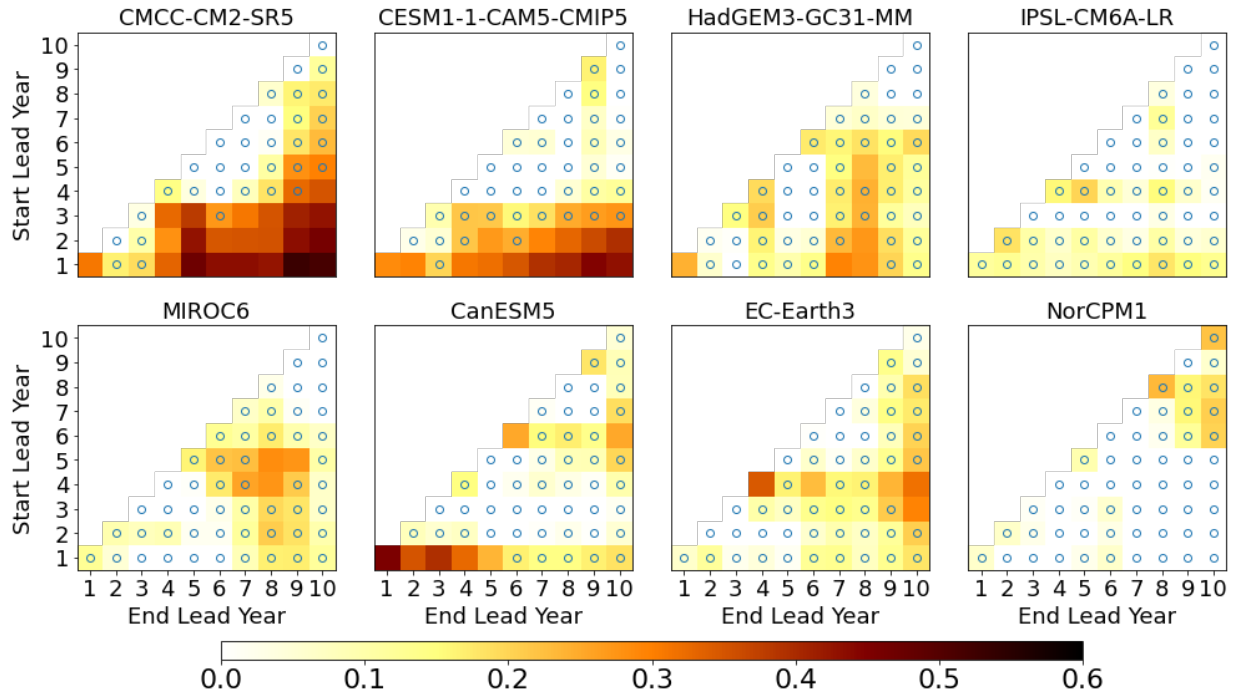
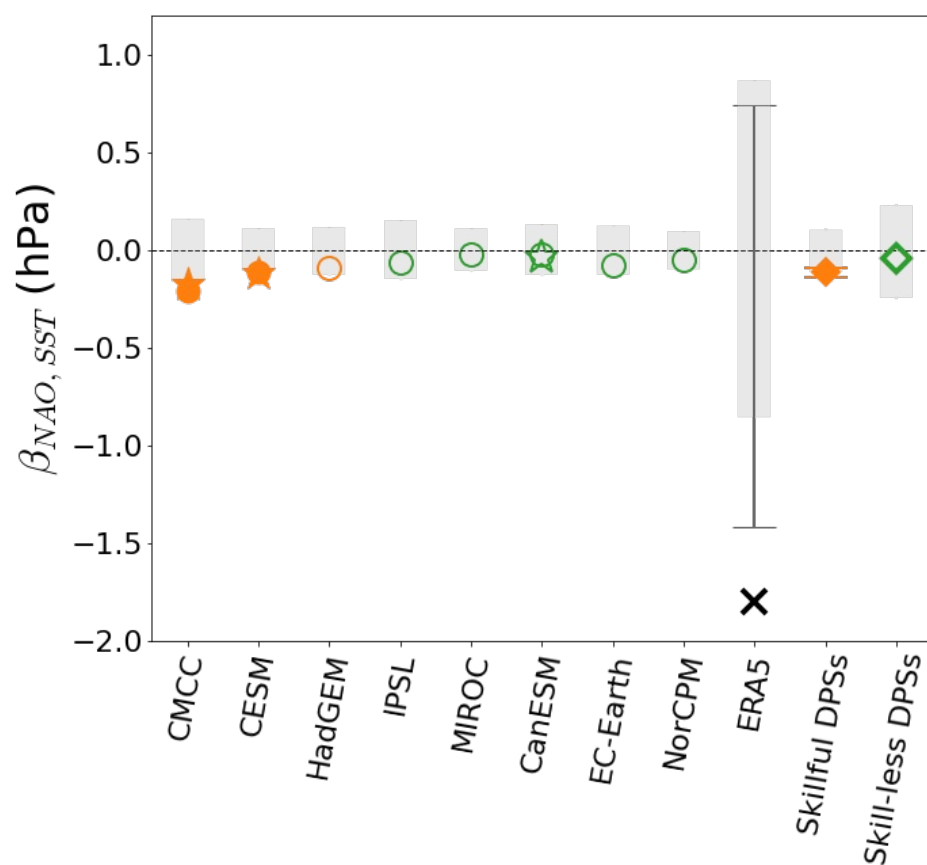
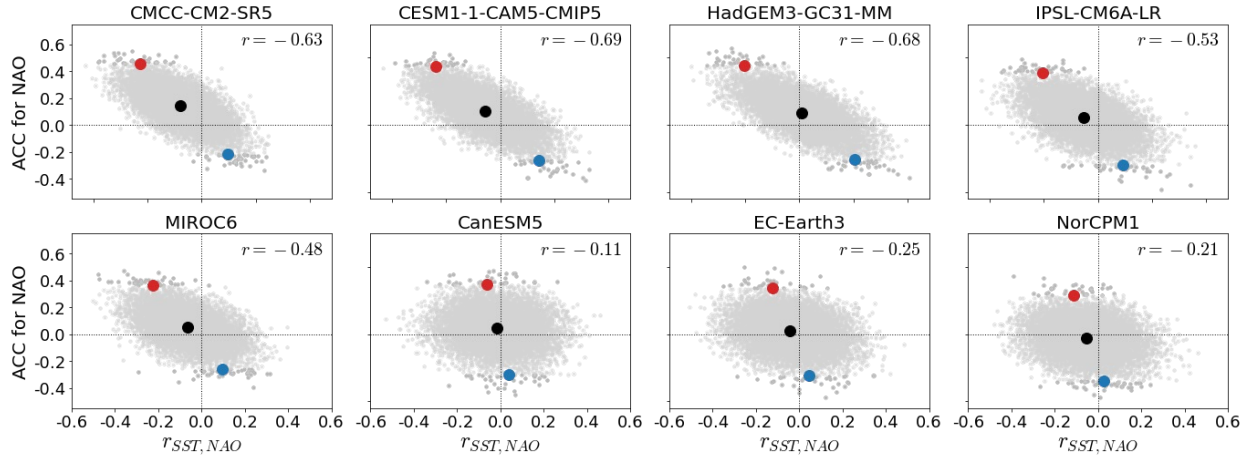




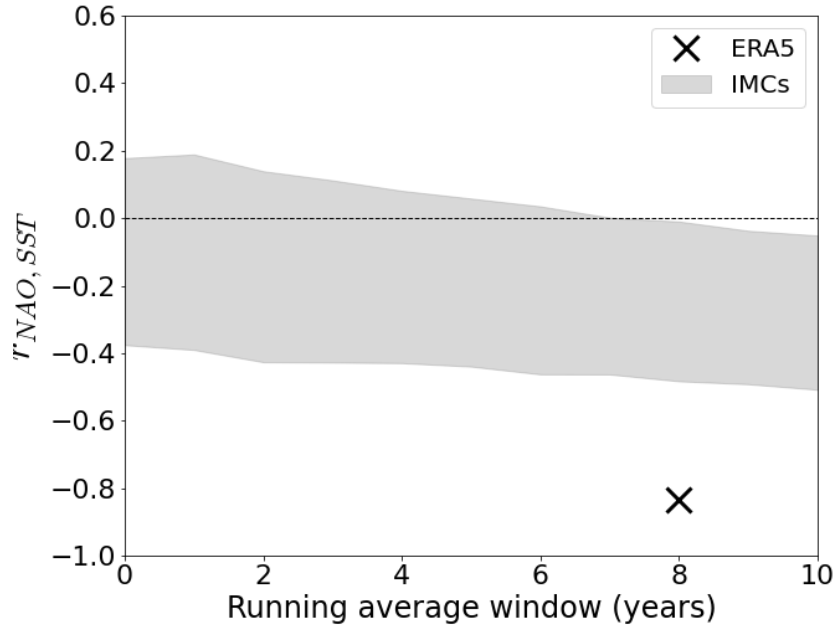
Supplementary Fig. 1: Dependency of NAO hindcast skill on forecast-year averaging range. The anomaly correlation coefficient (ACC) for the NAO is calculated using sea-level pressure (SLP) data from ERA5 and hind-cast output, which has been averaged over various forecast-year ranges defined by the start forecast-year (ordinate) and end forecast-year (abscissa). SLP from ERA5 has been smoothed with a running-average of window length equal to the forecast-year range prior to calculating the ACC for the NAO. The cyan markers indicate ACCs that are not statistically significant using a block-bootstrapping method (see Methods).



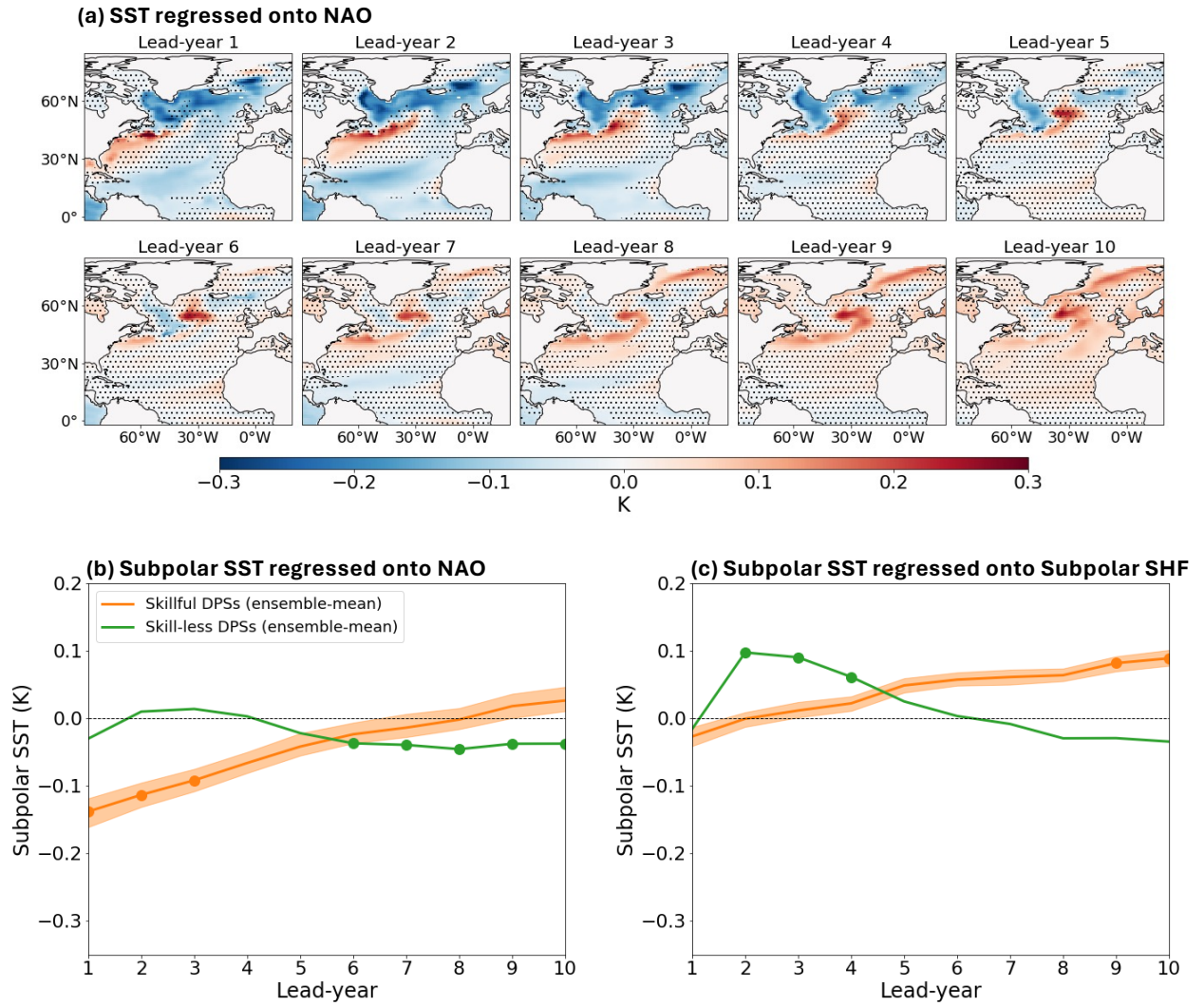
Supplementary Fig. 2: **Influence of Subpolar SSTs on the NAO** As in Figure 2b of the main text, except for the unstandardized NAO index (hPa) regressed onto the standardized subpolar SST index.



Supplementary Fig. 3: Relationship between the ACC for NAO and autumn subpolar SSTs correlated with the winter NAO ($r_{SST,NAO}$) in individual member combinations (IMCs) from all decadal prediction systems (DPSs). The ACC for the NAO and $r_{SST,NAO}$ is calculated for each IMC using fields that are averaged over FY1–8. $r_{SST,NAO}$ is calculated by correlating the winter NAO with the preceding autumn-season (SON) SST anomalies averaged over the subpolar North Atlantic region (50°N–65°N, 10°W–55°W). The correlation between the two variables across all IMCs is shown on the top right of each panel. The black marker indicates the average over all IMCs, and the blue and red markers indicate the 1st and 99th percentiles, respectively, of the ACC for the NAO.



Supplementary Fig. 4: **Effect of running-averaging on the correlation between autumn subpolar SSTs and the winter NAO ($r_{SST,NAO}$) in individual member combinations (IMCs) from the CMCC DPS.** SST and NAO indices for IMCs are calculated from fields averaged over forecast-years 1–8, and then smoothed along the initialization dimension with a running-average of varying window length (years) prior to calculating $r_{SST,NAO}$. The resulting spread in $r_{SST,NAO}$ across all IMCs is indicated by the grey shading. The observed $r_{SST,NAO}$ (cross marker) is calculated from ERA5 fields that have been smoothed with an 8-year running-average, as in Fig. 2 in the main text.



Supplementary Fig. 5: Evolution of ensemble-mean variables associated with the decadal NAO signal in the CMCC decadal prediction system (DPS), the skillful DPSs, and the skill-less DPSs. (a) Ensemble-mean annual SST anomalies (K) regressed onto the NAO signal at each forecast-year for the CMCC DPS. Areas without stippling indicate regressions that fall outside the 5–95th percentiles of the bootstrap regression distribution and are considered statistically significant (Methods). The NAO signal is calculated from the full ensemble-mean SLP from the CMCC DPS (20 members). (b) Ensemble-mean subpolar SST anomalies (K) regressed onto the NAO signal for the 60-member ensemble for the skillful DPSs (orange) and the 60-member ensemble for the skill-less DPSs (green). (c) As in (b), except for ensemble-mean subpolar SST anomalies (K) regressed onto ensemble-mean subpolar surface heat fluxes (SHFs). For skill-less DPSs, all 60 members are combined to calculate the ensemble-mean. For the skillful DPSs, 500 combinations of 60 members randomly selected out of the total 70 members (Methods). Lines indicate ensemble-means and shading indicates the respective spread. In (b) and (c), round markers indicate regressions that fall outside the 5–95th percentiles of the bootstrap regression distribution and are considered statistically significant. In all panels, the fields and regression indices have been averaged over forecast-years 1–8.